Introduction to the Special Issue on Statistical Analysis and Modeling of Automotive Emissions

Air pollutants generated through the combustion of fossil fuels present a difficult environmental challenge to society. Transportation, which depends heavily on fossil fuels as an energy source, is a prominent contributor to the problem. Emissions of carbon monoxide, volatile organic compounds, and nitrogen oxides, all of which affect local air quality and may cause public health problems, are at least partly attributable to transportation; and transportation is thought to be responsible for a large portion of the greenhouse gas emissions (e.g., carbon dioxide) that have recently been linked to global climate change.

Automobile usage represents a substantial portion of transportation in all industrialized countries, and the demand for automotive transportation absorbs much of the world's energy resources. Consequently, concerns about emissions on the part of the public, the media, and various governing bodies and health-related organizations have recently been more directly focused on the automotive sector. Over the past two decades, major public and private efforts have been undertaken in an attempt to more fully understand the complexity of automotive emissions; yet, despite these initiatives, the extent to which they harm the atmosphere and degrade public health, and the mechanisms by which they do so, are still not completely known. Nonetheless, policymakers in many industrialized countries continue to tighten the restrictions on automotive emissions in an ongoing effort to dampen their environmental impact. In some quarters, particularly within the business and economic communities, such initiatives have been met with determined resistance which, in turn, has contributed to the international debate concerning the ultimate social impact of the pollutants and policies designed to counteract them.

Unresolved air quality issues, the potential for climate change, and political opposition to increased regulation are prompting additional scientific and engineering investigation of automotive emissions and the methods used to control them. At the most basic level, the ability of policymakers to arrive at sound and reasoned decisions about an issue as complex as this depends on the availability of good data in sufficient quantities to support valid interpretations and conclusions. Unfortunately, for various reasons (not the least of which is cost), good emissions data can be difficult to come by, both in terms of quality and amount. Admittedly, an extensive body of information about automotive emissions exists. All kinds of emissions data are generated for various purposes through a wide range of experimental and operational programs, and the collection of such information is ongoing, with funding from various sources. Yet it frequently is the case that the right data are seemingly unavailable when it comes time to make a difficult public policy decision. There are always interacting and confounding factors to consider, which policymakers who are not experts in all the physical

mechanisms pertaining to automotive emissions can find difficult to disentangle. Further, emissions measurements exhibit some particular characteristics that often make their analysis less than straightforward.

In response to the obstacles presented by emissions data, statistical science is playing an expanding role in the establishment of emissions standards. A general recognition has emerged that statistical methods and models can provide the basis for making sound inferences about emissions effects and processes and that statistical thinking can provide the framework through which appropriate data collection is planned and executed. Nevertheless, statistical methods themselves can be misused or misapplied, thereby diminishing the benefits derived from their use and possibly even exacerbating the problems they are employed to resolve.

In recognition of the increasing role of statistical methods and modeling in the emissions arena, the Committee on Statistics and Statistical Software of the Transportation Research Board (TRB) of the National Research Council organized a mini-symposium of two technical sessions for presentation at the 1999 Joint Statistical Meetings (JSM) in Baltimore, Maryland. The American Statistical Association (ASA) sections on Statistics in the Physical and Engineering Sciences and Statistics in the Environment co-sponsored the two sessions with the TRB committee, chaired by Dr. Timothy Coburn of Abilene Christian University and Dr. Robert Mason of the Southwest Research Institute.

The principal goal of this mini-symposium was to foster interaction among individuals working on various statistical aspects of the emissions puzzle. The sense of the committee has been that, while much is being accomplished, it is being done by statisticians and engineers working in isolation who would greatly benefit from communication and exchange of ideas. A related objective was to promote greater overall consistency in the statistical treatment of emissions data and the use of appropriate methods. Finally, the committee sought to increase the dialog about automotive emissions within the professional statistical community for the purposes of stimulating new analytical approaches and enlightening policymakers about the need for statistical rigor.

This special issue of The *Journal of Transportation and Statistics* is devoted to the statistical analysis and modeling of automotive emissions. It contains many of the papers presented in the mini-symposium last August and also includes one additional manuscript submitted after the conference. The articles here represent the efforts of approximately 20 authors and co-authors from across industry, government, and academia and cover a diverse array of topics regarding fundamental methodological issues, advanced statistical techniques, and specific case studies. Two papers included in the mini-symposium but published elsewhere involved the assessment of sulfur in diesel fuel on the performance of emissions control devices and the forecasting of ozone standard exceedances that occur partly in response to vehicular traffic volume and dispersion.

The statistical analysis of automotive emissions is clearly a topic of current interest: the 1999 JSM is not the only recent venue to focus on it. For example, statistical applications were a major theme of the 2000 Spring International Fuels and Lubricants Meeting in Paris, co-sponsored by the Society of Automotive Engineers (SAE) and the Coordinating European Council (CEC), and several papers on the statistical analysis of emissions were presented there. Conferences sponsored by SAE and other professional organizations regularly include talks of this nature although they are not frequently organized into a single session or topical series. Likewise, since the early 1990s a substantial number of statistically oriented reports about automotive emissions have been published, and numerous related papers have appeared in a wide variety of technical journals. The growth in publications of this nature reflects both an increase in emissions research and the heightened emphasis on integrating the methods of statistical science. While by no means exhaustive, the bibliography provided on pages viii and ix is intended to be representative of the kinds and amount of statistical work that have been accomplished in this arena over the last ten years.

The use of statistical methods has contributed a great deal to an understanding of the origin and impact of automotive emissions, yet some important data-oriented problems remain largely unresolved. Many of these have to do with the sampling of vehicle populations. For example, determining the number and characteristics of all the vehicles in a large city so that a truly representative subset of those vehicles can be emissions tested is major undertaking. Other equally challenging problems include determining the correct sample size (the right number of vehicles) in the face of uncertainty and the spiraling cost of emissions testing, resolving the statistical requirements and operational difficulties of vehicle recruitment necessary to obtain an adequate sample, and knowing how to appropriately weight vehicle characteristics on the basis of actual usage or vehicle-miles traveled. Unresolved analytical questions exist as well, such as knowing how and when to mathematically transform emissions data to preserve distributional assumptions (e.g., use of the lognormal transformation), how to appropriately treat duplicate (or replicate) emissions measurements, and how to dispense with fixed and random factors in statistical emissions models.

It is the hope of the TRB committee that publication of this special issue of the *Journal* will serve to raise the level of awareness of these and similar issues. The goals are to foster development of the most realistic solutions possible to emissions-related problems and to provide the kinds of information necessary to produce improved decisionmaking and policy setting in the cross-disciplinary complex of energy, transportation, business, public health, and the environment.

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